~~178-DIG.002~~ 23

376/287

856,747 COMPLETE SPECIFICATION
2 SHEETS

This drawing is a reproduction of the Original on a reduced scale.
SHEETS 1 & 2

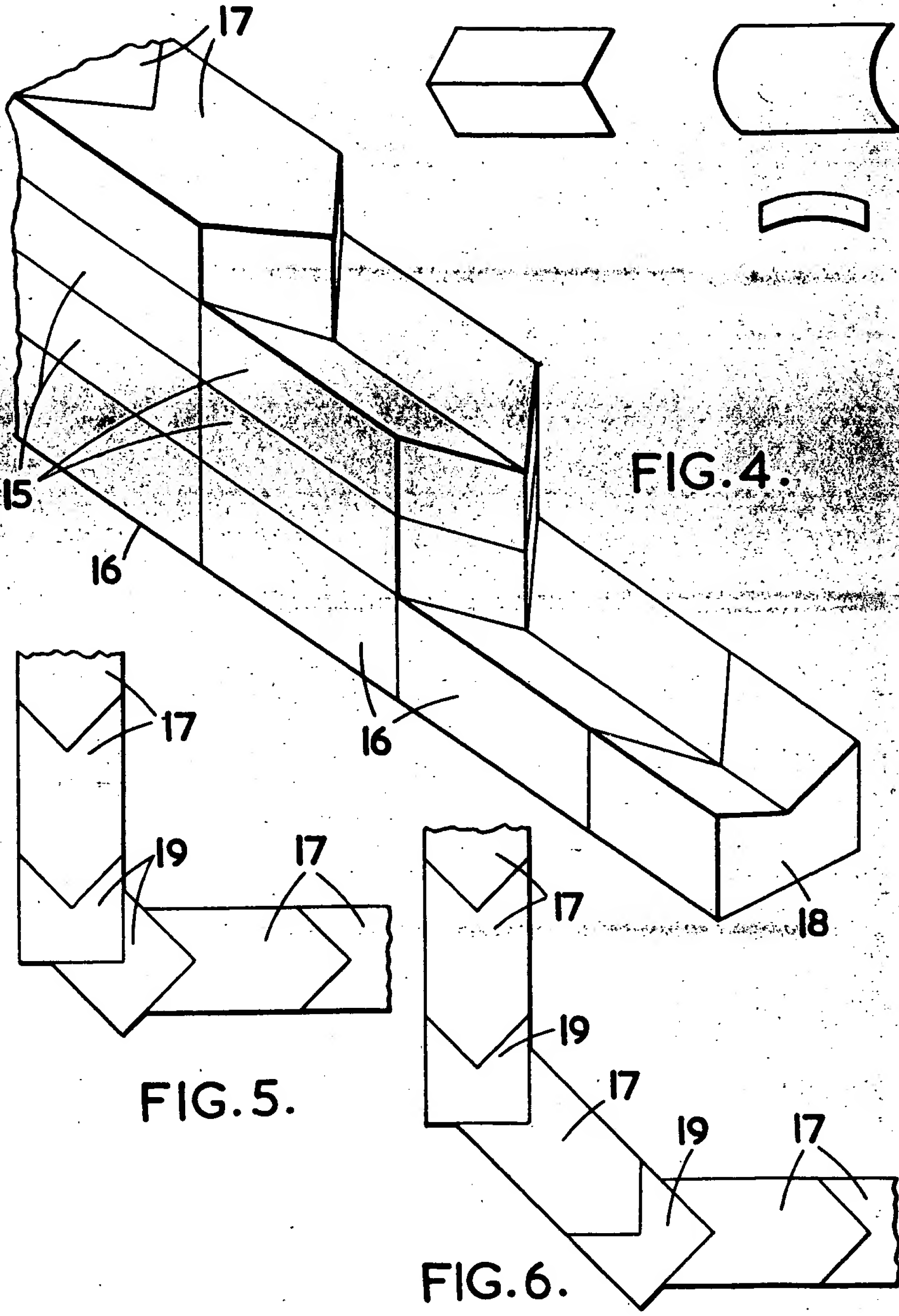

FIG.7.

FIG.8.

FIG.4.

FIG.5.

FIG.6.

~~178 DIG.002~~ 23

376/287

856,747 COMPLETE SPECIFICATION

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SHEETS 1 & 2

FIG.7. FIG.8.

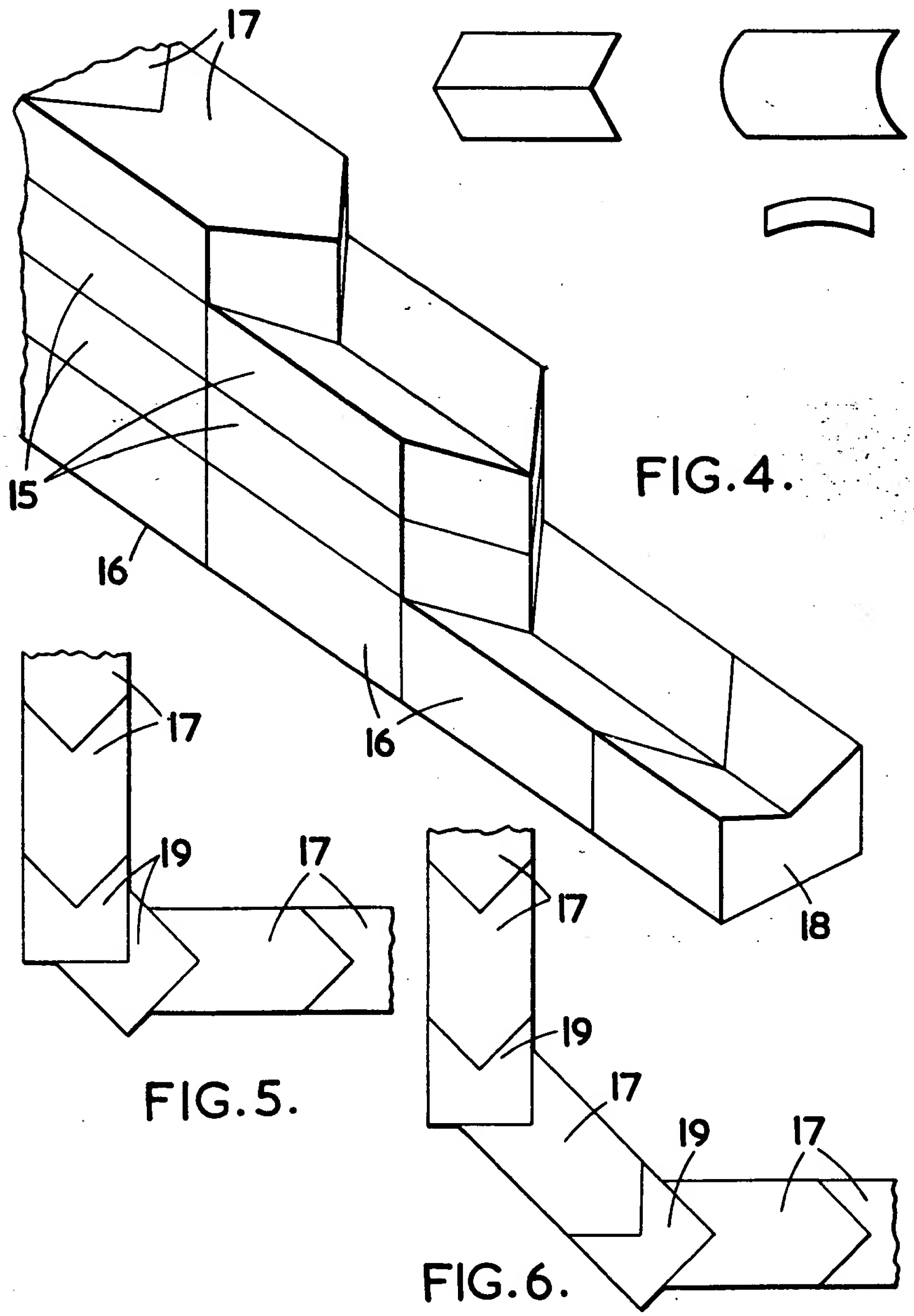

FIG.4.

FIG.5.

FIG.6.

376/287

~~204~~
154.36

PATENT SPECIFICATION

856,747

DRAWINGS ATTACHED.

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International Classification:—C04b. E04b, c. G21.

COMPLETE SPECIFICATION.

Improvements in or relating to Materials for Shielding Against Nuclear and Allied Radiation.

We, UNIBRIX RADIATION SHIELDINGS LIMITED, of 9, Arundel Street, Strand, London, W.C.2, a British Company, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The invention relates to materials for shielding against ionising and allied radiation, such as biological shields for nuclear reactors and shields against ionising radiation such as encountered in the manufacture and use of radioactive isotopes and X-rays.

The main requirements of a protective or shielding material for this purpose are that it shall be dense, homogeneous, not liable to the formation of cracks and fissures, physically and chemically stable under normal conditions of use and capable of being built into a shielding wall which is free from straight joints parallel with the direction of radiation. Such materials are also often required for the building of shielding walls of considerable size, for example, from upwards of 20 ft. high, and in such cases a further essential property is that the material shall have a high crushing strength.

Shielding walls are generally built as permanent structures of considerable size and wall thickness by employing the usual techniques of *in situ* concrete casting known in the building trade, and the density of such monolithic concrete structures is sometimes increased by using barytes aggregate. Such techniques always involve problems in the elimination of cracking, shrinkage, formation of pockets and segregation of materials which, if not satisfactorily overcome, would render the shield liable to dangerous leakage. They also raise problems of handling vast quantities of materials such as in the case of power station reactor shielding walls, which may be as high as 90 ft. and as thick as 15 ft. or more.

In the past, lead has been used to a great extent as a portable shielding material and, although it has the main requirement of high density, it is expensive and is also subject to cold flow, which limits the height to which the shielding wall may be built. Furthermore, lead can have poisonous effects when handled without suitable protection for the user. Lead has been used in the form of "chevron" shaped interlocking bricks, produced by extrusion or casting and subsequent machining of each individual brick to make it precision-finished, so that a completely tight interlock between each brick may be obtained when built into a shielding wall, thus eliminating any vertical or horizontal straight joints, which would allow gamma and other rays to travel straight through such joints causing radiation leakage. These bricks have a chevron or broad V shape both in plan and end elevation.

Another form of portable shielding block has been produced from cement and barytes, iron and other high density aggregates by the known method of casting into moulds, the advantage as compared with lead bricks being the very much lower cost, greater stability and higher crushing strength. On the other hand, one disadvantage is the lower density than lead and the blocks produced by such casting method are plain rectangular shapes or are provided with various forms of keying, but all have some straight joints which can allow a considerable proportion of the radiation to pass through the walls by way of these straight joints. A

further disadvantage in the application of such blocks is that they have to be erected when building the shield by staggering the alternate layers.

There is thus a demand for shielding material which fulfils adequately all the requirements mentioned above, but which is more easily handled than permanent monolithic structures, especially when the shielding walls required are not of extremely large size, and for a material which can be used either as permanent or temporary walls for a variety of applications wherever there is ionising radiation present such as in the nuclear industry, in research laboratories, in the medical field and in industry generally, where an ever-increasing use is made of radiation in a number of industrial processes. Such shielding materials are generally described as "portable", having the advantage that only limited or no mechanical means are required for their handling and erection, and shield made from them can be built "dry" without the use of cement or can be cemented into a homogeneous wall, if so required. In the former case, the dry wall shields can be dismantled or readily altered according to requirements and the portable units can also be stored away for later re-use.

Accordingly, it is an object of the present invention to provide a radiation shielding material which is not subject to the afore-mentioned disadvantages or at least materially reduces them.

According to the present invention, a method of making a block of radiation shielding material, comprises forming a mixture of a major proportion of at least one dense material and a minor proportion comprising at least one binder and compressing the mixture in a mould to form a dense homogeneous block under a pressure of at least 1,000 lb./sq. in., the dense material having a density sufficiently high to give to the block a density of at least 150 lb./cu. ft., and the moulded block being shaped so that a radiation shielding wall built from a plurality of such blocks excludes any straight joint therethrough.

The invention also comprises a block of radiation shielding material, which comprises a mixture of a major proportion of at least one dense material and a minor portion comprising at least one binder and which is made by compressing the mixture in a mould under pressure of at least 1,000 lb./sq. in., the block having a density of at least 150 lb./cu. ft. and being shaped so that no face of the block which is contacted by a face of another block in a radiation shielding wall comprising a plurality of such blocks is a single planar surface.

In order to avoid the formation of straight through joints when constructing shielding walls, the blocks of shielding material are preferably compressed in a mould which produces a block in which each face which is contacted by a face of another block in the shielding wall comprises at least two planar surfaces disposed at an angle to one another.

In a practical example according to the present invention, the blocks may consist of not less than 70% and preferably 80% to 95% by weight of the dense material, which may be barytes of a $BaSO_4$ content of not less than 85%, not more than 25% and preferably 5% to 15% by weight of cement as a binder with or without up to 5% of at least one material selected from pectates, oleates, fatty acid amines, amides or silicones, or alternatively, the barytes content of the mixture may be replaced partly or wholly by iron grit, ion shot, magnetite, witherite, calcined magnesite, haematite, limonite, ilmenite, galena, whinstone, (an intrusive doleritic quartz or basalt characteristic of the Whin Sill formation) copper refinery slag, steel punchings, or mixtures thereof. The barytes or other dense material can be partly replaced by one or both of mica and vermiculite. Up to 10% and preferably 3—6% by weight of water is added to the mixture prior to compression in the mould.

The mixture is pressed into blocks of the required fully-interlocking shape at not less than 1,000 lb./sq. in. pressure, preferably 2,000—3,000 lb./sq. in., and the blocks have a specific gravity of at least 150 lb./cu. ft. and a crushing strength of at least 1,500 lb./sq. in., a crushing strength in the range of 2,000—3,000 lb./sq. in. being suitable in most cases. Such a figure of crushing strength gives an ample margin of safety for building walls of the greatest height required without damage to the lower courses of blocks. The material also has sufficient resistance to shearing and tensile stress as to require no additional reinforcement and means of support.

In order that the invention may be readily understood, specific examples thereof are given below.

EXAMPLE 1.

A mixture was formed having the following constitution:—

90% by weight of barytes;
10% by weight of cement;
0.25% of pectates.

The barytes used had a minimum content of 90% $BaSO_4$ and was ground and graded to a particle size of $\frac{1}{2}''$ downwards. The cement and pectates were added in the proportions above stated and the whole thoroughly mixed in, for example, a paddle

mixer. Water or other wetting agent containing a minor quantity of a higher fatty alcohol sulphonate was added to bring the water content in the powder mix to 4—6%. The volume required in each block was measured by a volume box and charged into moulding boxes of a hydraulic press. A top pallette was placed in position and pressure applied to a minimum of 1,000 lb./sq. in.

EXAMPLE 2.

The following mixture was made up and used to make blocks in accordance with the procedure of Example 1.

85% by weight of barytes;
15% by weight of cement;
4—6% by weight of water and a minor quantity of at least one wetting agent, such as a petroleum sulphonate.

EXAMPLE 3.

The following mixture was made up and used to make blocks in accordance with the procedure of Example 1.

75% by weight of iron grit or iron shot;
25% by weight of cement;
3—5% by weight of water and a minor quantity of at least one wetting agent, as in Example 1 or Example 2.

Whilst a specific gravity of 150 lb./cu. ft. has been found suitable, a figure higher than this is possible to attain depending on the density of the raw materials used The density may conveniently be in the range of 200—350 lb./cu./ft.

After pressing, the blocks are ejected and removed to a storage rack where they are allowed to cure for one to three days in a moist atmosphere, after which they are air-dried for a period not exceeding twenty-eight days. The blocks may be given a final coat of a resin lacquer or silicones to render them dustless and proof against chemical attack.

Reference is made to the accompanying drawings, showing various forms of radiation shielding block according to the invention; in the drawings.—

Figs. 1, 2 and 3 show a preferred form of block for building the intermediate courses of a shielding wall, in end elevation, plan view and perspective view, respectively;

Fig. 4 shows a diagrammatic perspective view of part of a shielding wall including several shapes of block;

Figs. 5 and 6 show diagrammatic plan views of two different ways of forming a corner using blocks of the shapes illustrated in Fig. 4;

Fig. 7 shows a plan view and Fig. 8 shows plan and end elevational views of two blocks of further shapes.

The block shown in Figs. 1 to 3 has a pair of opposed rectangular flat side faces 10, a pair of opposed end faces each consisting of two planar surfaces one face being convex and formed by planar surfaces 11*a* and 11*b* and the other being concave and formed by planar surfaces 12*a* and 12*b*, and upper and lower faces each consisting of two planar surfaces, the upper face being concave and formed by planar surfaces 13*a* and 13*b* and the lower face being convex and formed by planar surfaces 14*a* and 14*b*.

The pairs of end face surfaces 11*a*, 12*a* and 11*b*, 12*b* are in parallel planes, as also are the upper and lower surfaces 13*a*, 14*a* and 13*b*, 14*b*. The end face planes intersect at 90° and the upper and lower face planes intersect at an angle preferably from 90° to 165° to one another, suitably about 140°, the intersections being located in the vertical median plane of the block.

Referring to Fig. 4, the partially-built radiation shielding wall comprises intermediate courses of blocks 15 each of the kind shown in Figs. 1 to 3. The base course comprises base blocks 16, which differ from the blocks 15 in having a flat lower surface and the coping course comprises coping blocks 17, which differ from the blocks 15 in having a flat upper surface. The figure also shows an end base course block 18, which differs from the blocks 15 in having a flat lower surface and a flat end surface. The complete wall includes six different kinds of end blocks, for the opposite ends of the base, intermediate and coping courses as will be readily understood.

Fig. 5 illustrates a right-angled corner in a wall, of which the coping course only is shown, formed by coping course blocks 17 and end coping course blocks, shown at 19. Due to the right-angle in the multi-planar end face of the blocks 19, each can be disposed with its concave end face against the end face corner of a similar block. A corner of 135° is shown in Fig. 6, in which one or more coping course blocks, one of which is shown at 17, is or are interposed between the end coping course blocks 19. This enables the construction of octagonal enclosures. As clearly shown in each of Fig. 5 and 6, the end faces of the blocks prevent the formation of any straight joints in the wall.

The intermediate course block shown in plan view in Fig. 7 is generally similar to the blocks 15 of Figs. 1 to 4, but differs in that the two planar surfaces constituting each end face have an included angle of 120° instead of 90°. This enables such blocks to be built into regular hexagonal shielding walls or other structures having corner angles of 120°. The further form of intermediate course block shown in Fig. 8 differs from the blocks 15 in that each end face

comprises a curved surface, one being concave and one being convex and having the same radius of curvature. Also, the upper and lower faces of the block are curved so as to be one convex and one concave.

It will be appreciated that base course, coping course and end-of-course blocks of the appropriate shapes can be derived readily from the blocks shown in Figs. 7 and 8 in an analogous manner to those described in connection with Figs. 4 to 6.

Various shapes and weights of the blocks are produced in order to build corners of shielding walls and also to provide for specially shaped shields to be erected. Such blocks conveniently vary from 10—30 lb. in weight, depending on the shape and size of the block and the materials used. For the bulk of the wall, i.e. the intermediate courses, a standard size block of between 20—25 lb. in weight has been found suitable and such a block may be made in a shape having an overall cross-section of 6″ × 4″ and plan dimensions of 6″ × 12″.

The blocks prepared as described present the substantial advantages of ease of erection and dismantling and avoidance of expensive mechanical handling plants on the site, whilst having sufficient density to absorb gamma radiation and sufficient hydrogen content to absorb fast neutrons.

WHAT WE CLAIM IS:—

1. A method of making a block of radiation shielding material, which comprises forming a mixture of a major proportion of at least one dense material and a minor proportion comprising at least one binder and compressing the mixture in a mould to form a dense homogeneous block under a pressure of at least 1,000 lb./sq. in., the dense material having a density sufficiently high to give to the block a density of at least 150 lb./cu. ft., and the moulded block being shaped so that a radiation shielding wall built from a plurality of such blocks excludes any straight joint therethrough.

2. A method as claimed in Claim 1, in which the dense material comprises barytes, iron grit, iron shot, magnetite, witherite, calcined magnesite, heamatite, limonite, ilmenite, galena, whinstone, copper refinery slag, steel punchings, or mixtures thereof.

3. A method as claimed in Claim 1 or 2, in which the dense material comprises at least 70% by weight of the mixture.

4. A method as claimed in Claim 3, in which the dense material comprises 80% to 95% by weight of the mixture.

5. A method as claimed in any preceding claim, in which the dense material comprises barytes having a $BaSO_4$ content of at least 85% by weight of the barytes.

6. A method as claimed in any preceding claim, in which the minor proportion of the mixture comprises cement.

7. A method as claimed in Claim 6, in which the cement comprises up to 25% by weight of the mixture.

8. A method as claimed in Claim 7, in which the cement comprises 5% to 15% by weight of the mixture.

9. A method as claimed in any preceding claim, in which the minor proportion of the mixture comprises at least one material selected from pectates, oleates, fatty acid amines, amides, silicones or mixtures thereof.

10. A method as claimed in Claim 9, in which the material comprises up to 5% by weight of the mixture.

11. A method as claimed in any preceding claim, in which the mixture has up to 10% by weight of water added thereto prior to compression in the mould.

12. A method as claimed in Claim 11, in which the mixture has 3—6% by weight of water added to it.

13. A method as claimed in Claim 11 or 12, in which the water includes a minor quantity of at least one wetting agent.

14. A method as claimed in any preceding claim, in which the mixture is compressed under a pressure of 2,000—3,000 lb./sq. in.

15. A method as claimed in any preceding claim, in which the mixture is so constituted and compressed as to produce a block having a density of 200—350 lb./cu. ft.

16. A method as claimed in any preceding claim, in which the mixture is so constituted and compressed as to produce a block having a crushing strength of at least 1,500 lb./sq. in.

17. A method as claimed in Claim 16, in which the block has a crushing strength of 2,000—3,000 lb./sq. in.

18. A method of making a block of radiation shielding material, substantially as hereinbefore described.

19. A block of radiation shielding material when made by a method as claimed in any preceding claim.

20. A block of radiation shielding material, which comprises a mixture of a major proportion of at least one dense material and a minor proportion comprising at least one binder and which is made by compressing the mixture in a mould under a pressure of at least 1,000 lb./sq. in., the block having a density of at least 150 lb./cu. ft. and being shaped so that no face of the block which is contacted by a face of another block in a radiation shielding wall comprising a plurality of such blocks is a single planar surface.

21. A block as claimed in Claim 19 or 20, in which each face of the block which is contacted by a face of another block in

the shielding wall comprises at least two planar surfaces disposed at an angle to one another.

22. A block as claimed in any of the preceding Claims 19 to 21 for inclusion in an intermediate course of a radiation shielding wall, comprising a pair of opposed side faces, a pair of opposed end faces mitred in parallel planes, the end faces being one concave and one convex and each comprising two planar surfaces, and upper and lower faces also mitred in parallel planes, the upper and lower faces being one concave and one convex and each comprising two planar surfaces.

23. A block as claimed in any of the preceding Claims 19 to 21 for inclusion in the base course of a radiation shielding wall, comprising a pair of opposed side faces, a pair of opposed end faces mitred in parallel planes, the end faces being one concave and one convex and each comprising two planar surfaces, an upper convex or concave face comprising two planar surfaces and adapted to support the lower face of an intermediate course block resting thereon and a base surface.

24. A block as claimed in any of the preceding Claims 19 to 21 for inclusion in the coping course of a radiation shielding wall, comprising a pair of opposed side faces, a pair of opposed end faces mitred in parallel planes, the end faces being one concave and one convex and each comprising two planar surfaces, a top surface and a lower convex or concave face comprising two planar surfaces and adapted to rest upon the upper face of an intermediate course block.

25. A block as claimed in Claim 22, 23 or 24, in which the planar surfaces of each end face are disposed at right-angles to one another.

26. A block as claimed in Claim 19 or 20, in which the block has curved upper, lower and end faces.

27. A block as claimed in Claim 22, 23, 24, 25 or 26, in which the upper face is concave and the lower face is convex.

28. A block as claimed in Claim 22, 23, 24, 25 or 27, in which the planar surfaces of the upper and lower faces are disposed at an angle from 90° to 165° to one another.

29. A block as claimed in Claim 28, in which the planar surfaces are disposed at an angle of 140° to one another.

30. A block as claimed in any of the preceding Claims 19 to 21 for inclusion in a base, intermediate or coping course of a radiation shielding wall at the end of a straight portion thereof and comprising a block as claimed in any of Claims 22 to 29 modified by having one flat end face and one non-flat end face.

31. A block as claimed in any of the preceding Claims 19 to 30, which is dimensioned so as to have a weight of 10 to 30 lb.

32. A block as claimed in Claim 31 for inclusion in the intermediate course of a wall, which is dimensioned so as to have a weight of 20—25 lb.

33. A block of radiation shielding material, substantially as hereinbefore described and as shown in the accompanying drawings.

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PROVISIONAL SPECIFICATION.

Improvements in or relating to Materials for Shielding Against Nuclear and Allied Radiation.

We, UNIBRIX RADIATION SHIELDINGS LIMITED, of 9 Arundel Street, Strand, London, W.C.2, a British Company, do hereby declare this invention to be described in the following statement:—

The invention relates to materials for shielding against nuclear and allied radiation, such as biological shields for the reactors of nuclear power stations and shields against ionizing radiation encountered in the manufacture of radio-active isotopes.

The main requirements of a protective material for this purpose are that it shall be dense, homogeneous, not liable to the formation of cracks or fissures, that it shall be chemically and physically stable under the normal conditions of use and water repellent. Such materials are often required for the building of shielding walls of considerable size for example from upwards of 20 feet high, and in such cases a further essential property is that the material shall have a high crushing strength. In the past lead has been used to a great extent as a shielding material, and, although lead has the main requirement of high density, it is expensive and is also subject to cold flow, which limits the height to which the shielding wall may be built. Furthermore, the biological shield for nuclear power stations must absorb both the gamma rays and the fast neutrons which are the products of nuclear fission, and lead is not so efficient in the latter respect as in the former. Con-

sequently other materials have been proposed in place of lead. Since, however, the efficiency of a material in shielding from gamma radiation is roughly proportional to the specific gravity such an alternative material must still be of high specific gravity although taking up considerably more space than lead. For example concrete has been employed as a shielding material in nuclear power stations in situations where space saving is not a critical factor. Other materials and compositions of specific gravity less than lead but higher than that of concrete have also been proposed, for example attempts have already been made to use a high specific gravity concrete for making shielding walls by employing the usual techniques of *in situ* casting known in the building trade for concretes and plasters, but these materials have generally been deficient in one or other of the essential respects. Also *in situ* casting techniques always involve problems of cracking, shrinkage, formation of pockets and segregation of materials which if not satisfactorily overcome would render the shield liable to dangerous leakage. Such methods also raise problems of handling vast quantities of materials, for example in the case of power station shielding walls which may be as high as 90 feet. There remains a demand for shielding material which fulfils adequately all of the requirements above mentioned but which is cheaper than lead and which can be applied equally well in large installations such as power stations, or in small installations such as medical centres or industrial plants dealing with isotopes.

We have found that materials which would otherwise be unsuitable as shielding materials on account of their mechanical properties may nevertheless be used to produce compositions suitable for use as shielding materials if steps are taken to improve the compressive strength during manufacture.

The present invention comprises a method of making a unitary block of radiation shielding material comprising mixing a major portion of a pulverised material of high specific gravity with a minor portion comprising binders and plasticisers and compressing the same into a dense solid homogeneous mass under a pressure of about 1,000 pounds per square inch.

The invention also comprises a composition having the property of shielding from radiation comprising a major portion of a pulverised material of high specific gravity and a minor proportion of binders and plasticisers the whole being compressed into a dense solid homogeneous block having a crushing strength greater than 1,000 pounds per square inch.

In the above context a high specific gravity means a specific gravity which is higher than that of concrete but less than that of lead.

In order to avoid the formation of straight through joints when constructing shielding walls the blocks of shielding material are compressed in a suitably shaped mould so that at least two pairs of opposite faces of the block are non-planar and allow such blocks to be interlocked with similar blocks placed above and below and end to end with respect to each other.

In a practical example according to the present invention the blocks consist of not less than 70% Barytes ($BaSO_4$) not more than 15% of cement with or without up to 5% of binders and plasticisers, which may consist of pectates, oleates, fatty amines, amides or silicones. The mixture is pressed into the blocks of the required shape at not less than 1,000 pounds per square inch and has a specific gravity of at least 4.0 and a crushing strength of about 1,500 pounds per square inch. Such a figure of crushing strength gives an ample margin of safety for building walls of the greatest height required without damage to the lower courses of blocks. The material also has sufficient resistance to shearing and tensile stress as to require no additional reinforcement and means of support.

A practical example of the process is as follows:—

The formula used is:
90% by volume of Barytes
10% by volume of cement with
0.25% of pectates included.

Barytes with a minimum content of 90% $BaSO_4$ is ground to a grain size of 300 mesh. Cement and pectates are added in the proportions above stated and the whole thoroughly mixed in a suitable mixer for example a paddle mixer. Water is added to bring the water content in the total mix to 15%. The volume required for each block is measured by a volume box and charged into a moulding box of the required shape. A top pallette is placed in position and pressure applied in a hydraulic press giving a minimum of 1,000 lb./sq. inch.

Whilst a final specific gravity of 4.0 has been found suitable, a figure somewhat lower than this is possible if due attention is given to the other requirements mentioned above. Also the Barytes may be replaced at least partly by other suitable materials, for example Limonite and/or magnetite.

After pressing the blocks are ejected and removed to a store rack, where they are allowed to cure for 3 days in a moist atmosphere, after which they are air dried for 4 days.

The blocks may be given a final coat of

resin, lacquer or silicones to render them dustless and proof against chemical attack.

Various shapes and weights of the blocks are possible but it has been found that a block of about 20 pounds weight is a very convenient unit. Such a block may be made in a standard shape having an overall cross-section of 6″ by 4″ and plan dimensions of 6″ by 12″. The upper and lower faces of the block are mitred in parallel planes, so that the upper face is concave and the lower face is parallel thereto and convex, and each of these faces is formed by a pair of planes which intersect in a plane passing through the long axis of the block. Such a construction avoids straight through joints when the blocks are placed on top of each other. Similarly the end faces of the block are also mitred in parallel planes so that the faces interlock with each other when assembled in a wall as horizontal stretchers, or when used as vertical stretchers.

The blocks prepared as described present the substantial advantages of ease of erection and dismantling and avoidance of expensive plant on the site, whilst having sufficient density to absorb gamma radiation and sufficient hydrogen content to absorb fast neutrons.

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